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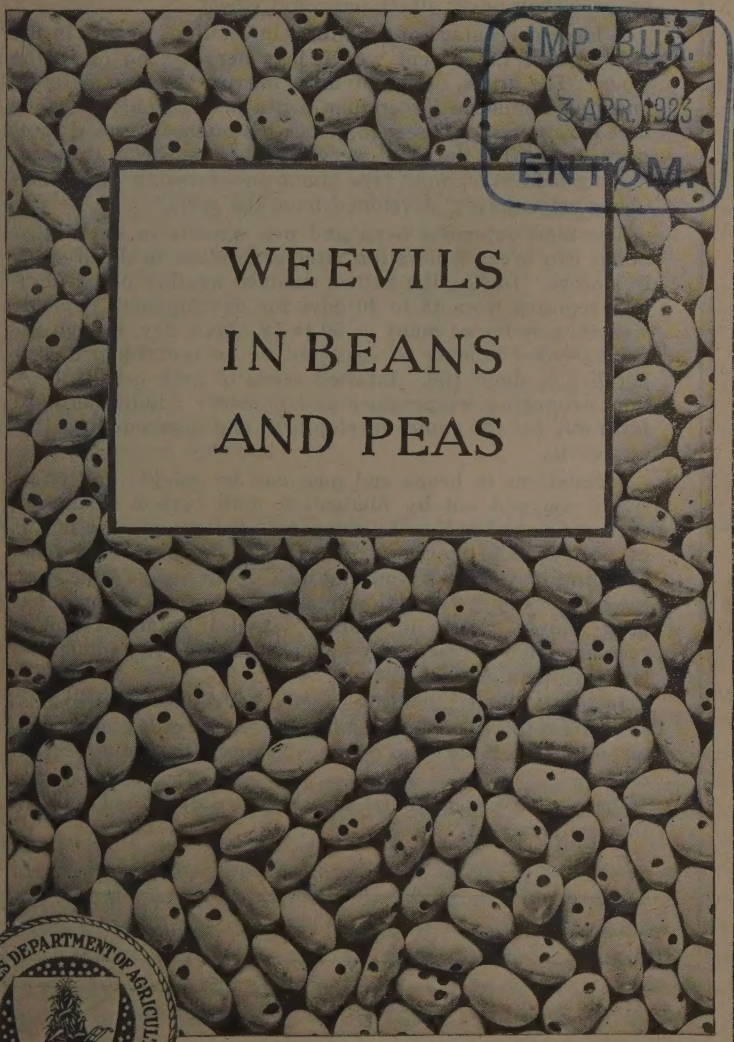

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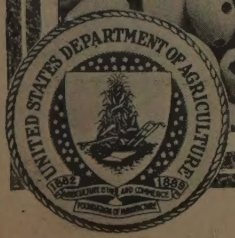
WEEVILS IN BEANS AND PEAS



BEANS, peas, and cowpeas are often damaged seriously in storage and in the field by weevils. Velvet beans, soy beans, and vetches are rarely infested in this country. Bean and pea weevils not only destroy much of the Nation's food in the form of leguminous crops but are responsible for a curtailment in the acreage planted to these crops. They never attack corn and wheat.

A large percentage of the initial infestations occurs in the field, where the parent weevil lays her eggs on or in the pods. The grubs, upon hatching, burrow into the seeds by gnawing a hole no larger than a pin prick. This entrance hole is usually not observed, hence the often expressed erroneous belief that the adult weevils that eat out from the seed, leaving behind a round hole about one-sixteenth of an inch in diameter, have "developed from the germ."

The most injurious bean and pea weevils in the United States can breed generation after generation in dried seeds in storage. During the hottest summer weather one generation requires from 18 to 30 days for development. Female weevils may lay as many as 50 to 58 eggs a day, though the average total number of eggs laid by an individual during her life is about 100. Infested seeds in bulk usually heat, thus producing temperature and moisture conditions most favorable for the rapid development and vigorous breeding of weevils.

Infestations in beans and peas can be quickly and effectively stamped out by fumigation with carbon disulphid, carbon tetrachlorid, or hydrocyanic-acid gas, and by means of heat or cold storage. Weevils can be prevented from breeding in storage by mixing dust or air-slaked lime with the seeds. Concerted action by a community of growers has been known greatly to reduce weevil infestations and is recommended unreservedly for consideration in commercial bean-growing areas.

In brief: Plant weevil-free seeds, harvest as soon as possible, treat to kill weevils, and store where seeds can be protected from reinfestation by weevils spreading from infested seeds.

Preventive and remedial measures are described fully in this bulletin.

Washington, D. C. August, 1922

WEEVILS IN BEANS AND PEAS.

By E. A. Back,

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SERIOUS LOSSES CAUSED BY BEAN AND PEA WEEVILS.

BEAN AND PEA WEEVILS are by no means new pests. They belong to a class of insects that cause farmers and merchants an annual loss of many millions of dollars. One Province of Canada alone suffered from the ravages of the pea weevil to the extent of over $1,000,000 in a single year. It was estimated in 1902 that the acreage in field peas in Ontario would have been 1,000,000 instead of the actual 532,639 planted, had it not been for fear of the pea weevil. Since the introduction from Europe of the broad-bean weevil into California about 1909, the pest is estimated to have reduced the acreage planted to Windsor beans 25 to 75 per cent, and in Alameda County, formerly a large producer, there is now practically no commercial acreage of these beans. The common bean weevil has been one of the chief factors in discouraging the production of field beans south of the latitude of New York, except in the higher altitudes, and is to-day one of the worst enemies of garden beans of all varieties grown in the East. Few realize that the ravages of this weevil

have forced farmers of many sections—as in the coastal regions of the Middle Atlantic States—to discontinue the production on a commercial scale of this valuable food crop and to turn their attention to other crops. The cowpea is now recognized as one of the most valuable cover crops for enriching the soil of the Southern States, and agriculturists claim that one of the drawbacks to its more general use for this purpose and for fodder is the susceptibility of cowpea seed to weevil attack. The cowpea weevils are the worst pests of cowpea seed. They are a big factor in maintaining, in years of normal production, the high cost of seed, and in the consequent curtailment of the use of this plant as a soil builder. These weevils, also, because of the rapidity with which they destroy cowpeas grown for human consumption, have caused seedsmen and merchants to view with suspicion cowpeas grown in certain sections of the South, and this attitude has had a depressing effect upon the production of cowpeas for food. Yet the South is a veritable Eldorado for the production of leguminous crops for food once weevils are controlled. It is evident, therefore, that bean and pea weevils should be charged not only with the damage they cause leguminous foods actually produced but also with the indirect losses to the country due to the reduction in the areas planted to beans, peas, and cowpeas.

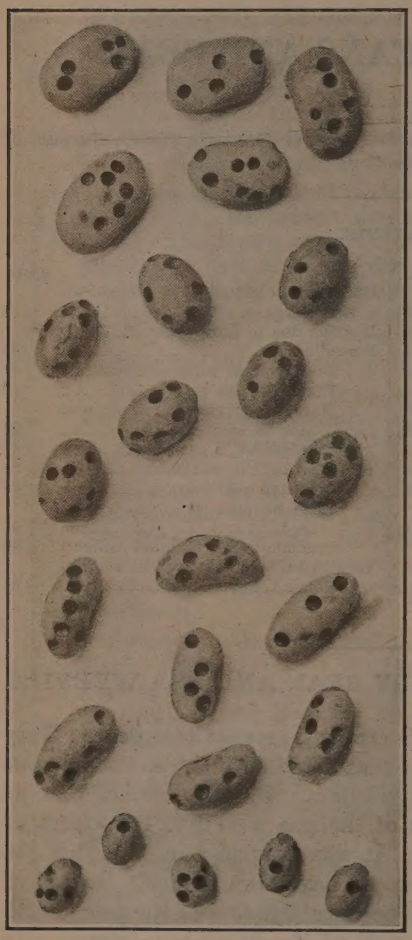

FIG. 1.—Navy beans showing the emergence holes of weevils. Each of these holes is made by a weevil as it matures in the seed and leaves by cutting out a piece of the skin. All except the five small beans at the bottom have been injured by the common bean weevil. The five small beans were grown in Central America and are infested by the Mexican bean weevil. About natural size.

LOSSES OFTEN DISCOVERED TOO LATE.

Injury to edible legumes usually is observed first after the crop has been in storage for several months. Many believe that once the crop has been harvested it needs no further attention. Seeds put away at time of harvest are sometimes not examined again until the following planting season, when they are found "buggy" or "weevily" and badly damaged. The town or city gardener has proudly put away for winter consumption beans grown during the previous summer, only to find them worthless as food and full of

FIG. 2.—Field peas in bloom. Adult pea weevils begin laying their eggs on the young pods in the field. It should be remembered that the bean and pea weevils begin their attack on the seed while the crop is developing in the field. Photo by Vinal.

holes and honeycombed by grubs when later he opens the jar or sack in which they have been stored. Wonder is often expressed that seeds apparently sound when put away for the winter, and kept always well covered, should be found later injured by weevils. Because small round holes (see title page and Fig. 1) and weevils appear later in seeds seemingly perfect when harvested, a belief is current among many that bean and pea weevils develop spontaneously from the germ of the seed. That there is no foundation for such a belief is shown by the facts following.

HOW BEANS AND PEAS BECOME INFESTED.

Bean and pea weevils, like many other insect pests, pass through several marked changes in form and habits before reaching maturity. The story of development is shown in Figure 3. The weevil that is

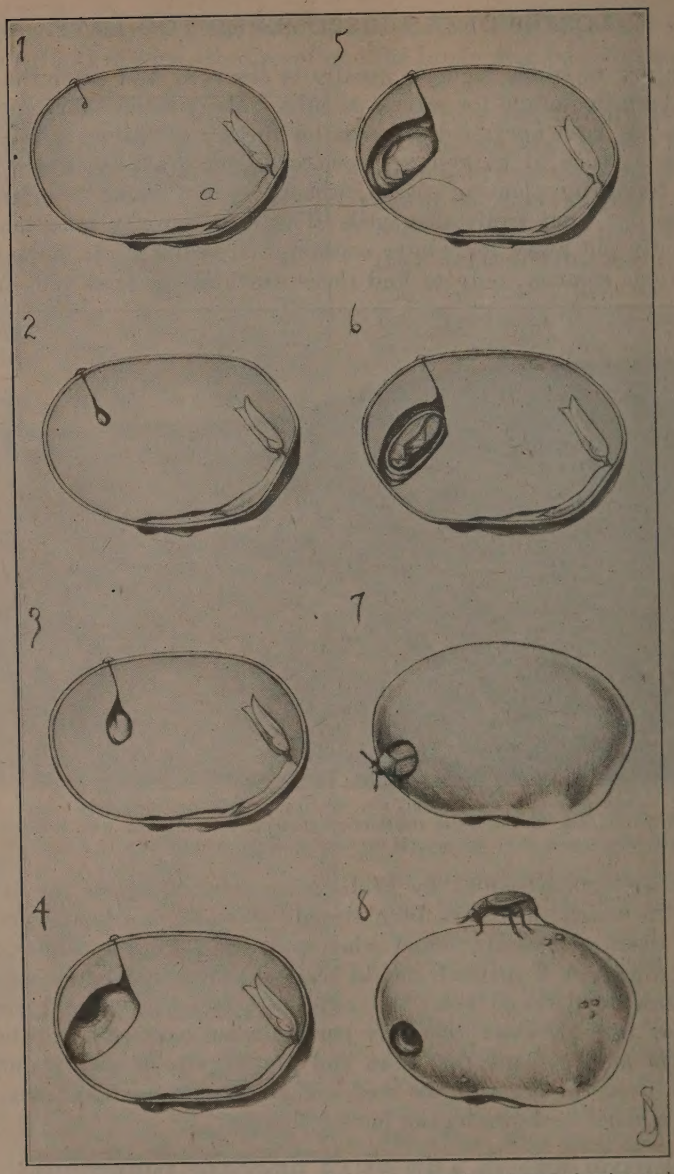

FIG. 3.—Life cycle of a bean or pea weevil: 1, Cross-section of seed showing embryo or germ at *a*, and on upper left side an eggshell and the small burrow made by the newly hatched grub from the underside of egg into the seed; 2, 3, and 4, larva or grub in different periods of growth, the larva of 4 being full grown; 5, pupa or resting stage which is intermediate between the larva and the adult; 6, side view of beetle within the pupal cocoon and ready to gnaw the round hole in the seed coat so it can crawl out of the seed; 7, beetle has eaten a circular hole in the seed coat and is crawling out; note that this emergence hole is some way from the point of entry; 8, female beetle laying eggs upon the seed.

seen crawling about among the seeds is the parent insect. Many of these fly from the storage room or house to the fields where beans and peas (Fig. 2) are growing. As the bean and pea pods develop, the mother weevil lays whitish eggs, either on the outside or within the pods. These eggs are so small that they are often not noticed, for they appear as mere white specks upon the pods. From these eggs there hatch white grubs that burrow their way through the pod into the soft developing beans or peas. Because these grubs are so very tiny, the holes through which they enter the seeds are too small to be seen unless one searches for them with a microscope. Usually beans become infested first when they are nearly or quite full grown. As seeds expand and harden in the final ripening proc-

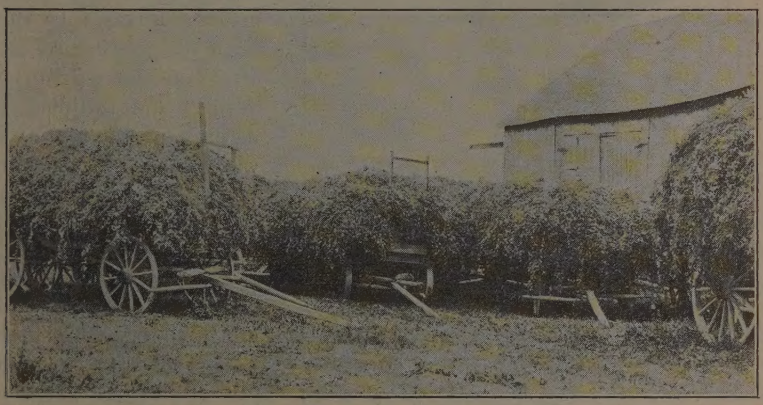

FIG. 4.—Wagon loads of field peas brought to mill to be thrashed. Remember that the pea weevil, the broad-bean weevil, and the lentil weevil are the only weevils mentioned in this bulletin that can not breed in dried seeds in storage. For this reason any infestation by these weevils occurs only in the field while the crop is maturing; hence the weevil grubs are in the seeds at the time they are harvested, shelled, or thrashed, and any treatment at that time, if done thoroughly, will prevent the development of holes in seeds resulting from the emergence of adult weevils.

ess the holes in the skin through which the grubs entered become less and less easy to find. The wound in the skin either becomes entirely healed over or remains similar in appearance to a small pin prick.

Since beans and peas mature much faster than the weevil grubs within them, it happens that the weevil grubs are comparatively small or little developed, in many instances, when the crop is harvested (see Fig. 4) and placed in storage. Thus many seeds that appear outwardly in excellent condition in reality have weevil grubs hidden away in their interior, as shown in Figure 3.

WHERE WEEVILS IN STORAGE COME FROM.

At harvest time grubs developing from eggs laid on or in the pods in the field may have devoured very little of the seed contents, but if the seeds are stored in a warm place, or in a climate where the weather is sufficiently warm, they continue to feed and become well grown. When well grown they have eaten out of the seed contents a cavity somewhat larger than themselves and extending outward to, but not pucturing, the skin of the bean. (Fig. 5.) The grub then changes or transforms into the pupa (Fig. 10, *c;* Fig. 12, *c*) and later into the adult. This adult has a pair of sharp jaws which it uses like a pair of scissors to cut out a circular flap (see Fig. 6) in the bean skin, thus making the small round hole which is, to most gardeners, the first evidence that insects are in their beans. Through these openings the adults crawl out and by their presence in sealed jars and other containers cause much concern.

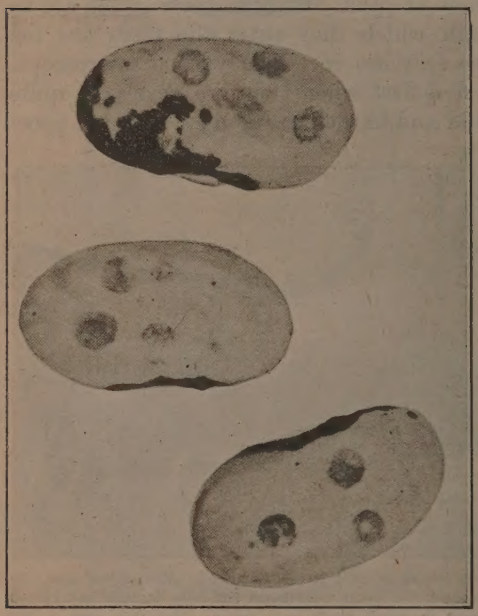

FIG. 5.—Beans in which the common bean weevil grubs have become full grown and have eaten out from the interior of the bean to, but not puncturing, the skin. As they transform to adult, each insect darkens and this dark color shows through the thin skin and makes the dark, sometimes bluish, translucent spots in beans. Such spots indicate that seeds are infested. It should be remembered that while the grubs are still growing they are white, and seeds do not indicate their presence by any such dark spots as shown above. Considerably enlarged.

DESTRUCTION CONTINUES IN STORAGE.

With the exception of the pea weevil that attacks the different varieties of peas, the broad or Windsor bean weevil, and the lentil weevil, the weevils attacking beans and cowpeas continue to produce generation after generation in dried seeds in storage. (Fig. 7.) The pea and the broad-bean weevils will die in storage and can not reproduce unless they can find growing plants in which to lay eggs. But the ordinary bean and cowpea weevils lay eggs for successive generations as readily upon dried seeds in storage as upon the growing plants

in the field. As each generation of weevils reduces the value of seeds for planting and for food, steps should be taken to kill, at harvest time, such grubs as may be in the seeds and thus prevent further losses. If this is not done the seeds become honeycombed by the feeding of generations of grubs and may be reduced to a powder. (Fig. 8.) Because bean and cowpea weevils can breed in dried seeds it is important not to store uninfested seeds near seeds that are infested, for the weevils spread rapidly and will soon infest the newer seed.

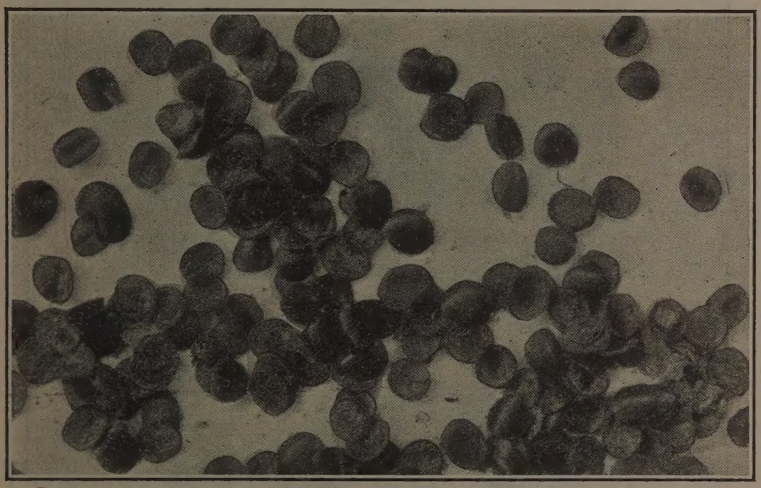

FIG. 6.—In escaping from beans, peas, or cowpeas, or any host, weevils leave behind them the small round holes familiar to all. In making these holes they use their jaws to cut around the dark spots shown in Figure 5 and then push away the circular flap of skin just as one opens a tin can of preserved fruit with a can opener. These circular bits of skin, shown above, about 4 times natural size, may be found among the seeds.

THERE ARE DIFFERENT KINDS OF WEEVILS.

Injury to leguminous crops is caused by more than one insect. Those considered in this bulletin are the pea weevil,[1] the common bean weevil,[2] the cowpea weevil,[3] the four-spotted bean weevil,[4] the broad-bean weevil,[5] the lentil weevil,[6] and the Mexican bean weevil.[7] These are all commonly found in supplies of beans, peas, cowpeas, or lentils in this country. Other species are sometimes found in imported seeds, but will not be discussed here.

[1] *Bruchus pisorum* Linnaeus.
[2] *B. obtectus* Say.
[3] *B. chinensis* Linnaeus.
[4] *B. quadrimaculatus* Fabricius.
[5] *B. rufimanus* Boheman. [6] *B. lentis* Boheman. [7] *Spermophagus pectoralis* Say.

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GENERAL DESCRIPTIVE FACTS.

The bean and pea weevils of the United States are all very small. None of them is longer than one-eighth to one-fifth of an inch.

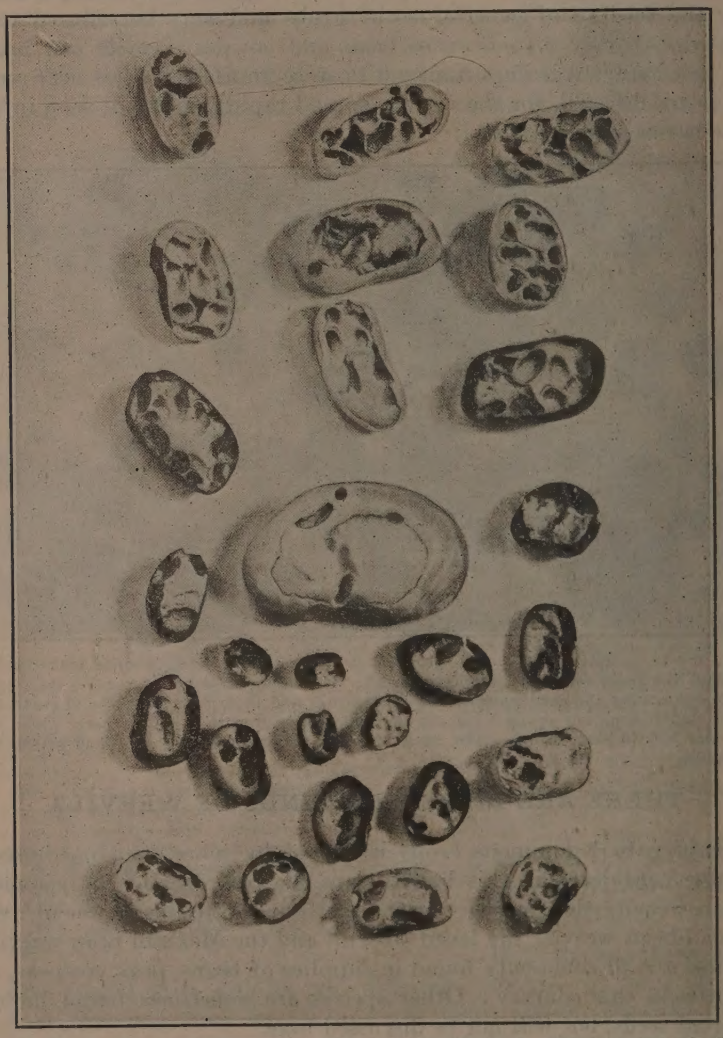

FIG. 7.—Various types of beans and cowpeas cut lengthwise to show how severely they may be damaged by bean and cowpea weevil grubs. Such beans and cowpeas are not fit for human food. Slightly enlarged.

They are dull-colored with markings of white or black. For the general shape, size, and arrangement of these markings, see Figures 10, 12, 13, 16, 19, and 20. Their eggs are from one-fiftieth to one-

twenty-fifth of an inch long, white or whitish, and appear as specks (see figs. 14 and 15) when laid on beans and cowpeas in storage.

The larvæ, or grubs, naturally are very small when first hatched and are white in color. After feeding they become somewhat maggotlike in general appearance, being nearly cylindrical, fleshy, dis-

FIG. 8.—Leguminous crops may be reduced to a powder by the continued feeding of weevil grubs. In the bottom of sacks or boxes in which weevily beans or cowpeas are held for a long time one finds quantities of dead weevils and the powdered remains of the seeds such as are shown above. About natural size.

tinctly wrinkled, more or less curved in outline, and not more than one-fourth of an inch long and usually less.

By the time the grub has become full grown it has eaten out in the seed contents a cell in which to transform to the pupa or chrysalis. Before transforming it secretes a substance which hardens into a white, filmy cell about itself, and this serves to protect the helpless

pupa while the changes to the adult are taking place. For the general shape and appearance of the grub and pupa see Figures 10, 12, and 16, *b* and *c*, and Figure 13, *c*. The pupal cells are shown in Figure 22. For the general life cycle see Figure 3.

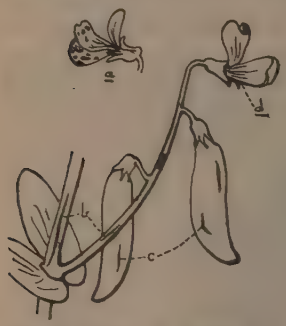

FIG. 9.—Plant of garden pea showing, at *a*, holes in blossom where pea weevil beetles have fed; at *b*, slits in stem; and at *c*, cuts in pods made by the feeding beetles. The beetle finds its favorite shelter at *d*. (Skaife.)

THE PEA WEEVIL.[8]

The pea weevil is the most serious enemy of the field or garden pea. It now occurs over almost the entire globe wherever peas are cultivated. It is scarcely known, however, in the colder countries of northern Europe and does comparatively little damage for the most part in the coldest sections of Canada and the United States. Continuous cropping of land to peas naturally leads to a constant increase in the number of pea weevils, as evidenced by the fact that garden peas grown almost anywhere in the United States, except in places in our more northern States or in high altitudes, are apt to be badly affected. This pest was causing serious damage to garden peas in Pennsylvania, New Jersey, and southern New York as early as 1748.

The pea weevil is a small grayish or brownish-gray beetle about a fifth of an inch long and marked with black and white spots as shown in Figure 10. The short line to the right of *a* in the illustration gives the actual length of the beetle. The adults appear on the vines when the peas come into bloom. They are said to feed principally on the petals of the pea flowers and on the succulent tissues of the stems and pods as shown in Figure 9. While they eat holes in the petals and gnaw out long narrow slits in the stems, they do not appear to damage the plants materially, as the damaged flowers produce normal pods and the slits in the stems soon heal over and do not cause wilting.

FIG. 10.—Pea weevil: *a*, Beetle; *b*, larva or grub; *a*, pupa. The line to the right of the adult (*a*) represents the actual length of the beetle, and the sizes of the larva and pupa are in proportion. (Chittenden.)

The adults show a strong tendency to remain dormant during the season of the year when growing peas are not available for attack.

[8] *Bruchus pisorum* Linnaeus.

Thus while certain beetles having access to pea plants lived only four or five weeks, others were found alive in dried seeds 14 months after the seeds were gathered. The female weevils lay their yellowish eggs singly upon the surface of the pods to which they attach them with a peculiar viscid secretion. The young grub upon hatching gnaws through the pod and burrows into the seed where it does practically all its feeding. While as many as six young grubs have been found in single seeds, it is seldom that more than one matures and emerges. (See Fig. 11.)

The length of time required for the eggs to hatch and for the grub or larva to mature into the adult of the next generation varies with the climate. In the District of Columbia adults have appeared as early as July 21. Others have been reared as late as the middle of August. A very considerable portion of the beetles mature and leave the seeds in the latter part of the summer in the latitude of Washington, D. C., but farther north and in higher altitudes the adults remain in the peas until the following spring, when they emerge in storage or are planted with the seed. It is in the adult stage that the weevil passes the winter, hibernating either in secluded spots in fields or buildings or in the pea seed itself. *The pea weevil has only one generation a year and can not reproduce in dried peas.*

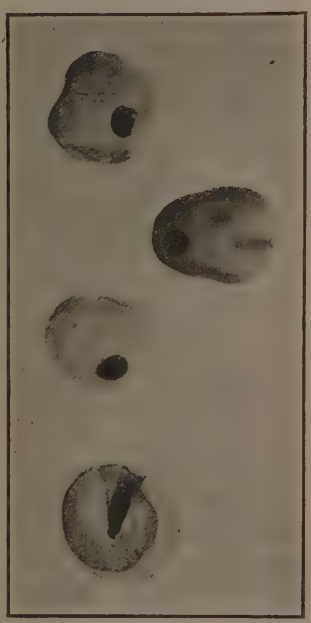

FIG. 11.—Garden peas showing exit hole of the pea weevil. Note that only one weevil develops in a single pea. One seed has been sectioned to show cavity made by grub. Enlarged.

THE COMMON BEAN WEEVIL.[9]

The common bean weevil is the most formidable enemy to the culture of beans in the United States as well as in many other countries. It occurs in nearly every State, the Territory of Hawaii, and is generally distributed throughout Mexico, Central America, and South America. It has been found in beans imported from southern Europe, Persia, India, China, Algeria, South Africa, Madeira, the Azores, and the Canary Islands. Commerce has carried it to all the larger markets of the world. So severe is its attack in the warmer sections of this country that dried beans for seed and for food are grown mostly in the more northern States and California.

[9] *Bruchus obtectus* Say.

In the coastal region of the Middle Atlantic States and farther south bean growing is made very difficult, if not rendered unprofitable, by the unmolested increase of the bean weevil.

The bean weevil is smaller than the pea weevil, being only about an eighth of an inch long, and shaped and marked as illustrated in Figure 12. The adult, or beetle, is so coated with fine hairs that it appears brownish gray or olive color. Unlike the pea weevil, the bean weevil not only can develop in growing beans in the field, but also can breed generation after generation in dried beans in storage.

The adults may live as long as nine weeks, though usually two weeks represents their more normal length of life during the active season. Of course, adults may remain alive in a dormant condition for several months in dried seeds during cold weather.

FIG. 12.—Common bean weevil: *a*, Beetle; *b*, larva or grub; *c*, pupa. The short line to right of the beetle (*a*) represents its real length. (Chittenden.)

The female weevils fly from storage or hibernating quarters early in summer and from then on may be found upon the bean plants. While the weevils lay their eggs in largest numbers through cracks in the pod that develop during the drying-out of the pod, the female has been observed to gnaw holes in green pods and to lay her eggs through such holes. Eggs are never glued to the outside of the pod as is the habit of several other species of bean and pea weevil. In storage the eggs are laid singly and loosely (i. e., unattached) among the seeds. As many as 26 eggs may be laid by a single female in one day, and a total of 85 eggs during her life. Sometimes as many as 67 eggs have been found laid through a crack in a bean pod.

As many as 28 weevil grubs have been found in a single bean. All varieties of garden beans are attacked, even lima beans being severely damaged during 1920 and 1921 in New England.

Experiments have demonstrated that the eggs of the bean weevil require from 5 days in the hottest weather to 20 days at a cooler temperature to hatch, and that the larvæ or grubs become full grown in from 11 to 42 days and the pupæ in from 5 to 18 days, according

to the temperature. It requires 21 to 80 days at least, according to the season and locality, for a generation of the bean weevil to develop. In the District of Columbia there may be as many as six generations a year. The warmer the climate the greater the number of generations and the consequent damage done by the grubs.

In a climate similar to that of the District of Columbia and adjacent parts of Maryland and Virginia adults of the first generation started in the field begin to emerge as early

FIG. 13.—Cowpea weevil: *a*, Adult male; *b*, eggs; *c*, postembryonic larva; *d*, front view of head of same; *e*, thoracic leg of same. *a*, Much enlarged; *b–e*, more enlarged. (Chittenden.)

as October If the fall is early and the seeds are stored in a cold place no adults may emerge before the following spring. If seeds are stored in a warm place adults may emerge at any time during the winter. After emergence in storage the adult females lay eggs either on the beans or on the sides of the receptacles in which the seeds are stored.

THE COWPEA WEEVIL.[10]

The cowpea weevil (Fig. 13) is a foreign species first described from China but now widely distributed in dried seeds over the entire United States. It has been recorded from every continent and is likely to be

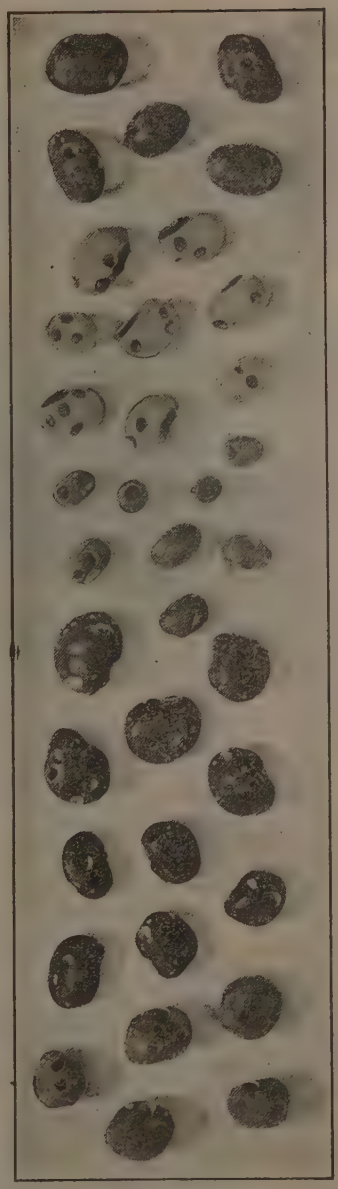

FIG. 14.—Different varieties of cowpeas showing infestation by cowpea weevil. Seed about natural size; the white specks on the seeds are the eggs of the weevil.

[10] *Bruchus chinensis* Linnaeus.

found in cowpeas in any commercial center. Although it prefers cowpeas (see Fig. 14) and is, with the four-spotted bean weevil, the worst pest that the cowpea has, it may attack the common pea, pigeon pea, lentil, chick-pea, mung bean, and common white bean.

The adult weevil is about an eighth of an inch long and may be distinguished from weevils discussed in this bulletin by the elevated ivory-like spots near the middle of the body, as shown in Figure 13.

Like the bean weevil, the cowpea weevil usually begins to infest cowpeas while they are developing in the field by laying its eggs upon the pods. It also is able to breed generation after generation in stored cowpeas and often reduces them to a powder. Because of the very warm weather of the Southern States, where the cowpea weevil is most severe in its attack upon cowpeas, the grubs mature very fast and often the adults may emerge as soon as the crop is ripe. In a fairly warm or indoor temperature six to eight generations may mature annually in a climate like that of Washington, D. C.

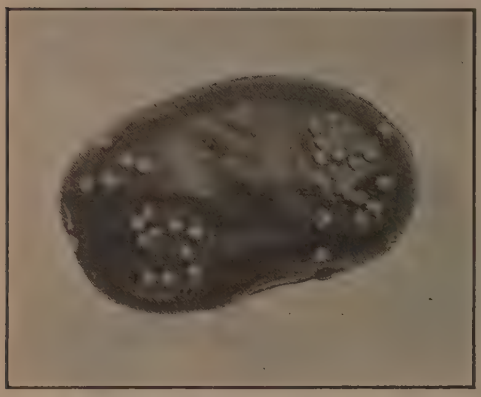

FIG. 15.—A cowpea seed showing eggs of a cowpea weevil. The eggs of bean and pea weevils vary in shape but are always small, ranging in length from one-fiftieth to one twenty-fifth of an inch. They are white or whitish, and may be laid anywhere upon the outside of the seed, as indicated here, or in cavities in the seed made by a previous generation of grubs, or on sides of containers such as burlap sacks, barrels, etc. The eggs can be distinctly seen on seeds, as tiny white specks. Much enlarged.

The beetles may live as long as 36 days, although the average life is probably about 12 days. At an average temperature of about 70° F. eggs may hatch in 8 days, larvæ become full grown in 17 days, and the pupa stage passed in 7 days; thus giving 32 days as the time required for the development of one generation from egg to adult. During very hot weather a generation may mature in as few as 18 days (egg, 3 days; larva, 12 days; pupa, 3 days) to 21 days (egg, 4 days; larva, 13 days; pupa stage, 4 days). During cooler weather 45 days (egg, 10 days; larva, 25 days; pupa, 10 days) and 60 days (egg, 10 days; larva, 40 days; pupa, 10 days) were required. Of course this period may be extended to cover three or four months during winter weather.[11]

[11] Chittenden, F. H. The Cowpea Weevil, U. S. Dept. Agr., Bur. Ent. Bul. 96, Pt. VI, 1912.

The adults live on an average 5 or 6 days during the hottest weather, to as many as 30 to 40 days during the winter months of the Gulf Coast States. Activity is likely to cease entirely at a mean temperature of 50° F., or below, when the insects will seem dead to all outward appearances and only resume activity upon the appearance of warm weather. While the immature stage may be passed in as few as 16 to 17 days, 21 days is closer to the normal time required during hot summer weather. The longest period for larval development yet recorded is 88 days, from December to March, in Texas, when the temperature ranged from 22° to 86° F. There may be from 8 to 10 generations a year in the Gulf Coast States.

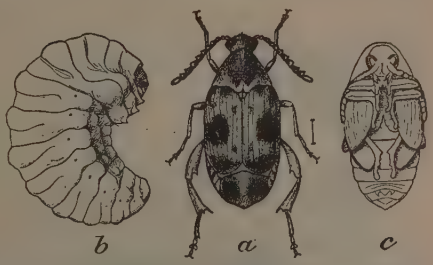

FIG. 16.—Four-spotted bean weevil: *a*, Beetle; *b*, larva or grub; *c*, pupa. Enlarged. (Chittenden.)

FIG. 17.—Chick-peas affected by the four-spotted bean weevil. Compare these with the two sectioned chick-peas at the bottom of Figure 22. Enlarged.

THE FOUR-SPOTTED BEAN WEEVIL.[12]

The four-spotted bean weevil somewhat resembles and is a trifle larger than the cowpea weevil, but may be distinguished from it not only by its more slender body but by the four black spots upon its wing covers as shown in figure 16.

In 1885 this species was found to be swarming on black-eyed peas from Texas exhibited at the Atlanta Cotton Exposition. Since then

[12] *Bruchus quadrimaculatus* Fab.

it has been found attacking cowpeas throughout the Southern States and as far north as Iowa and is probably present wherever cowpeas are grown. The cowpea is its favorite host food, although peas and beans are attacked (see Fig. 17). It is undoubtedly a more serious pest of cowpeas than the cowpea weevil discussed above because it seems to be more hardy. Although females may lay eggs upon the pods in the field, it breeds most prolifically in seeds in storage, gluing its small white eggs to the seeds.

FIG. 18.—Lentils of two varieties showing injury by the lentil weevil. While only one lentil weevil matures in a single seed, it is capable of practically destroying that seed, as indicated by the sectioned seeds at the bottom of the illustration. Somewhat enlarged.

THE LENTIL WEEVIL.[13]

The lentil weevil is not known to be established in this country at the present time, although it has been found repeatedly in imported lentils from Europe. It is an enemy of the lentil crop in middle and southern Europe, Egypt, and Syria. While lentil growing is on the increase in this country, it is hoped to keep this pest from becoming established in North America.

FIG. 19.—Mexican bean weevil: Adult weevil with line to left indicating actual length. Infested bean to left showing two emergence holes and six eggs. (Chittenden.)

The lentil weevil, only one of which matures in a single seed, resembles somewhat the pea weevil but is only about an eighth of an inch long. Like the pea and broad-bean weevils, it has but one generation a year. Lentils showing the

[13] *Bruchus lentis* Boheman.

emergence holes and injury caused by this weevil are illustrated in Figure 18.

THE MEXICAN BEAN WEEVIL.[14]

The Mexican bean weevil is an inhabitant of South and Central America and is frequently found at our Pacific and Atlantic ports, infesting beans imported from these countries. It attacks beans and cowpeas. It breeds continuously in dried seeds and is capable of being as injurious as the common bean weevil, as indicated by the five small beans affected by this pest, shown at the bottom of Figure 1. For the size, shape, and coloration of this insect, see Figure 19. The adult lays her eggs upon the seeds, to which they are stuck by a cement similar to that used by the cowpea weevil (Fig. 15.) While occasionally intercepted at ports of entry for many years past, this species does not appear to have become established in the United States.

FIG. 20.—Adult of the broad-bean weevil. Greatly enlarged. (Chittenden.)

THE BROAD-BEAN WEEVIL.[15]

The broad-bean weevil closely resembles the common pea weevil, being about the same size, one-fifth of an inch long, and of similar

FIG. 21.—A broad, horse, or Windsor bean, grown in California, cut open to show the damage caused by grubs of the broad-bean weevil. Only one generation of this weevil occurs each year. As each cavity represents the feeding of one grub, this bean is badly affected. Considerably enlarged.

appearance. It can, however, be readily distinguished by its much narrower thorax and fainter markings, as a comparison of Figures 20 and 10 will show.

[14] *Spermophagus pectoralis* Say. [15] *Bruchus rufimanus* Boheman.

The broad-bean weevil (Fig. 20), sometimes called the European bean weevil, is common and destructive in Europe and North Africa. While it feeds upon various sorts of beans and peas, it appears to prefer the broad or Windsor beans (see Fig. 21). Although it has been found from Canada to Texas in Windsor beans imported into various parts of this country, the first discovery of its definite establishment in the United States was made in 1909 at San Luis Obispo, Calif., where it was injuring the broad or Windsor bean (*Vicia faba*) grown for stock feed.

Since then, and up to 1920, it has spread to include the coastal counties of California, from Sonoma to San Luis Obispo, besides San Benito, Santa Clara, Alameda, San Joaquin, Sacramento, Yolo, and Napa. Practically every bean entering the warehouses of New York is often more or less damaged by this pest. A single grub in its development consumes approximately 3 per cent of the bean. Sometimes as many as six weevils develop in a single bean. Beside the actual amount of seed consumed there must be considered the frass of the insect left behind in the seed and this still further reduces the value of the crop. It has been stated that of the entire broad-bean crop of California for the years 1916, 1917, and 1918, 31.21, 18.01, and 43.08 per cent, respectively, were above the 15 per cent limit of weevil infestation allowed by the Federal pure food law, and therefore could not be shipped unless hand picked. In 1916 the average percentage of infestation for the entire 1916 crop in the Halfmoon and Gilroy regions was above the 15 per cent limit, while the same is true for the Sacramento and Halfmoon districts for the 1918 crop. After a campaign of seed fumigation in San Mateo County during 1918, 1919, and 1920, it was reported that the percentage of the broad bean crop infested 15.1 per cent or more was reduced from 43 per cent in 1918, to 21 per cent in 1919, and to 17.8 in 1920. Since beans uninfested, or infested less than 15 per cent, were worth during these years from 5 to 6 cents per pound, and others only 2½ to 3 cents, it is easy to appreciate the dollars and cents value of concerted action among growers in applying cheap, but effective, remedial measures.

The following biologic facts are taken from a report of experiments conducted at Alhambra, Calif.[16] The egg stage lasts from 9 to 18 days, the larva stage from 10 to 15 weeks, the pupa stage from 7 to 16 days, and the beetle lives from 1 to 8 months. The eggs are laid on the green bean pods in the field from the middle of March to the middle of May; the larvæ reach maturity from August to October, while the adults can be found from August to the following June. The broad-bean weevil has but one genera-

[16] Campbell, R. E. The Broad-Bean Weevil. U. S. Dept. Agr. Bul. 807. 1920.

tion each year and can not start new generations in dried seed in storage. That is, such beetles as emerge from the seeds in storage have developed exclusively from eggs laid in the field upon the green pods and can do no further injury in warehouses.

WHY WEEVILS LIMIT ACREAGE PLANTED TO CERTAIN LEGUMINOUS FOOD CROPS.

It has been pointed out already that infestation nearly always takes place in the field while the crop is maturing. With garden or Canada peas, lentils, and broad or Windsor beans infested with the pea weevil, the lentil weevil, and the broad-bean weevil, respectively, this is always the case, for these weevils never breed in dried seeds. Other species that breed in dried seeds, as well as in the field, may spread in storage to uninfested seeds and badly infest them. It is generally known that the colder the winters the shorter the growing season and the fewer the bean and pea weevils that survive the cold of winter and are ready to fly to the fields to start the infestation of the growing crop by laying eggs upon the pods. The farther south one goes the more mild the winters become, the longer the growing season, and the greater number of weevils that can live through the winter.

As far south as the District of Columbia and the adjacent tidewater country of adjoining States, therefore, overwintering weevils attack the beans and peas in large numbers and succeed in years favorable for them in laying so many eggs upon the pods that each developing bean becomes affected and often may support as many as 20 to 28 weevil grubs. Because of the long, warm falls and the length of time the plants are allowed to remain in the field after the crop has ripened, either standing in the ground or pulled and stacked, these grubs are given every opportunity to develop into adults or at least to become very well grown in an unusually large number of cases, and therefore they cause greater damage than do weevils in bean fields farther north. Thus beans grown in latitudes south of New York City, except in higher altitudes, as in the mountainous regions of the Alleghenies, become more infested than those grown north of that latitude. As weevils in beans are not killed so easily as are many other insects, and as their presence in numbers in beans is objectionable whether beans are grown for food or for planting, even when the grubs have been killed (see Fig. 22), the growing of beans on a commercial scale for dried seeds has largely been given up in our more southern latitudes. This explains the question often asked why beans and peas grown in portions of California, Michigan, New York, Washington, Oregon, or Idaho, or even in Canada, find their way into our southern markets, which one would expect should

be supplied by southern-grown beans and peas. Practically all the dried beans grown for seed and for food are grown in these northern States where the bean weevils are not able, because of climatic checks, to cause so much damage. Of course weevils do not affect the growing beans to be eaten green, as "string beans" or green shelled beans, for such beans are not, at the time of gathering, infested; or if infested, the grubs are too small to interfere with their value as food.

FIG. 22.—Beans (six upper seeds) and chick-peas (two lower seeds). The skin of the beans has been removed to reveal the cavities eaten out by the common bean weevil grubs. The grubs have been killed by fumigation and have turned black. Note the white paper-like cell or cocoon about each of the grubs. The chick-peas have been cut open to show how the larvæ of the four-spotted bean weevil can burrow to the very center of the seed. Slightly enlarged.

GERMINATION AFFECTED BY WEEVIL ATTACK.

The germination of beans, peas, and cowpeas is likely to be seriously affected by the development of weevil larvæ. If the embryo is destroyed by the larva, or if too much of the bean substance is eaten, the seeds can not grow.

Beans as badly infested as those shown in Figures 1, 7, and 23 are worthless for planting. As the young bean or pea plant depends upon the food stored in the seed to give it its first start, the destruction of any portion of the seed by weevils lessens by so much the vigor of the plant. In one experiment on record, only 50 per cent of infested beans germinated, and of these 30 per cent were so badly injured that they could not develop into normal plants. The smaller the seed, the greater proportional damage a single weevil grub can cause. One grub ruins a small cowpea seed (see Fig. 14) or a lentil (see Fig. 18), whereas it would not so seriously affect a large seed like the lima bean. The germination of broad beans infested with 1, 2, 3, and 4 or 5 broad-bean weevils was found to be reduced from a normal of 95.7 to 82.7, 72.7, 71.1, and 69.6 for new crop seed. In examining 50 garden peas infested by the pea weevil 33 were found with the embryo wholly or partially destroyed and in another case only 69 out of 275 infested peas had undamaged embryos or germs.

HEATING DUE TO INFESTATION.

It is a well-known fact that beans and peas, as well as grains, will heat if insects become sufficiently abundant in them. In bean warehouses where the seeds are stacked as shown in Figures 26 and 27, centers of weevil infestation can be detected by walking past the tiers of sacks and allowing the hand to pass over the sacks. Experience soon makes it easy to detect heating sacks. Heating seeds also produce an odor quickly detected by experienced persons when they enter a warehouse after it has been closed for a few hours.

The ability of bean and pea weevils to produce heating of the seeds is of great importance. Were it not for this ability, owners could

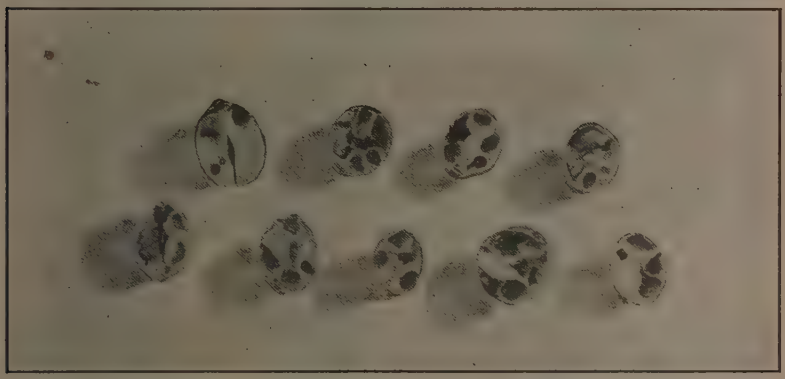

FIG. 23.—Navy beans cut crosswise to prove how the common bean weevil can ruin seeds for eating or planting. About natural size.

rest assured that if warehouses were open to outdoor temperatures below 50° F. no injury from weevils would take place. Certain weevils develop most quickly when the temperature ranges between 75° and 95° F. and egg laying is greatly stimulated by these higher temperatures. At temperatures ranging from 75° to 95° F. development of the four-spotted bean weevil has been known to be completed in as few days as 18; hence heating caused by weevil infestation, with the accompanying increase in moisture content of the seeds, may result in an outbreak of weevils at a season of the year when least expected. The temperature of a 240-pound sack of chick-peas infested by the cowpea weevil and the four-spotted bean weevil may be raised by infestation to at least 103° F. It is not uncommon in some warehouses to find a considerable number of sacks the temperature of which has been raised to over 80° or 90° F. In one instance, when the daily maximum temperatures ranged between 50° and 58° F., sacks within 2 feet of an open window registered 102° F. The temperature in the spaces between heating sacks was raised in this ware-

house from 58° F. to a minimum of 70° F. and a maximum of 78° F. At 58° F. adult weevils were too cold to migrate, but at 70° to 78° F. they were very active and were spreading from heating sacks to surrounding sacks and laying eggs upon previously uninfested seeds.

This effect of heating, due to infestation upon spread of injury from sack to sack, to say nothing of increase in infestation within the individual sacks during cold weather, should be understood by those holding beans and peas, else a genuine loss will come upon them unawares. Fumigation with hydrocyanic-acid gas (p. 29) kills the insects, reduces the temperature to normal, and stops spread. Fumigation with carbon disulphid or carbon tetrachlorid will doubtless do the same.

REMEDIES.

No group of seed pests can be more easily controlled in storage than pea and bean weevils. Once seeds are dried and housed they can be protected from destruction. Owners should watch their crop and apply treatment at the first sign of infestation. Any remedy that lessens the number of weevils present in the field has a direct effect upon the number of weevils to be fought in storage, and vice versa.

DO NOT PLANT INFESTED SEEDS.

If seeds are planted that contain weevils, the adults emerge from the seed after it has been planted and live in the field until the pods are sufficiently developed to receive the weevil eggs. They add their numbers to those in the field that have migrated from the place of seed storage. To plant peas, beans, and cowpeas containing living weevils only invites a "buggy" crop. Since the pea and broad-bean weevils can not breed in dried seeds, peas intended for planting may be held over for one year in tight paper bags so that the weevils that emerge can not live but will die before the second spring. Beans and cowpeas affected by other weevils should be treated.

PRACTICE CLEAN CULTURE.

In gathering the crop leave as little of it as possible in the field. Seeds scattered on the ground or left in scattered pods on the dried vines can carry the pest over winter and furnish a supply of weevils the following summer to offset the trouble taken to kill the weevils in storage and in seeds for planting.

HARVEST, THRASH OR SHELL, AND SACK AS SOON AS POSSIBLE.

Because some adult weevils emerge in the late summer and fall, according to the latitude, leguminous crops subject to weevil attack

should be harvested as soon as possible after reaching maturity. The seed should be thrashed or shelled at the earliest possible moment in order that the seeds may be more easily and cheaply treated to

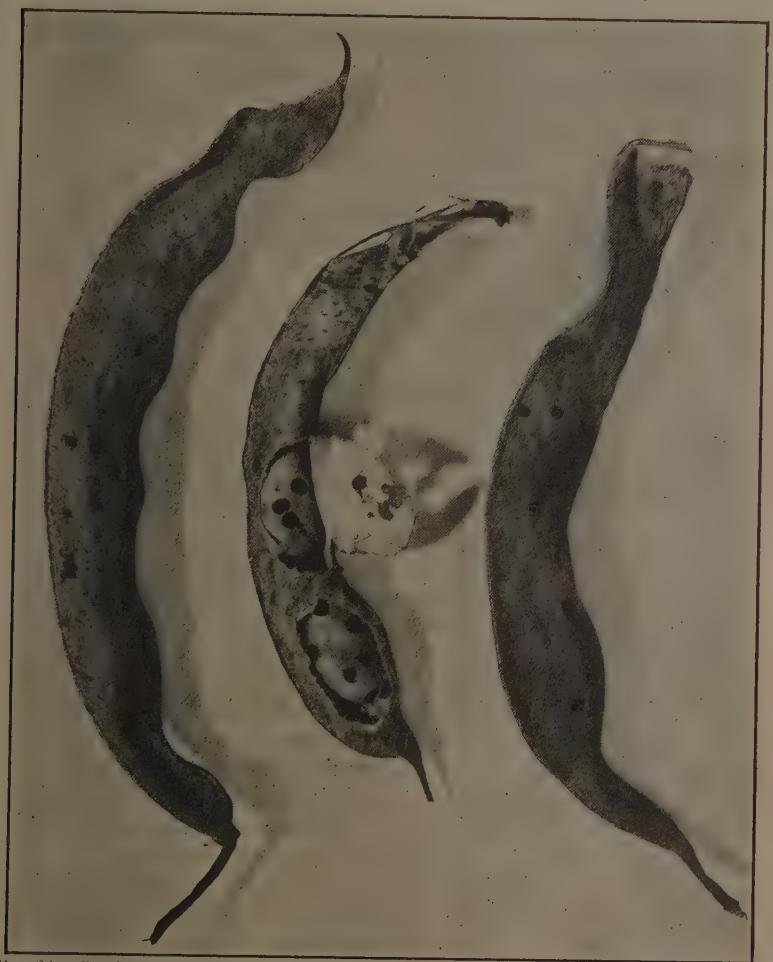

FIG. 24.—Storing beans, peas, or cowpeas in the pod will not prevent the weevils from ruining the beans if they are already in the seeds. Neither will it prevent them from emerging, as indicated by the holes they have made in the pods shown above in making their escape from the seeds. One pod has been cut to expose the infested beans within. Work of the common bean weevil. Enlarged.

keep the weevil grubs from feeding and maturing. Storing in the pod does not confine the weevils. The grubs continue their development and transform to the adult in the unshelled as well as in the shelled seeds. Adult weevils can gnaw their way out of dried

pods, as shown by the exit holes in the pods of Figures 24 and 25. The weevils in large bulks of unthrashed or unshelled beans or peas can not be satisfactorily treated. There is only one answer to the often-asked question, "Is it better to store beans or peas in the pod or shelled?" Shell the seeds and treat them if you expect weevil injury.

FIG. 25.—Pod of field pea showing exit hole of cowpea weevil. This pod was taken from a bale of field pea hay grown in Florida and indicates that even field pea hay grown only for cattle food may be instrumental in offsetting community cooperation to lessen weevil injury. Somewhat enlarged.

FUMIGATION.

Weevils may be killed in storage by fumigation with carbon disulphid, carbon tetrachlorid, or hydrocyanic-acid gas.

CARBON DISULPHID.

Fumigation with carbon disulphid (CS_2) is one of the simplest remedies for weevils. The nature and use of this fumigant is discussed in Farmers Bulletin 799, which can be had upon request from the United States Department of Agriculture. Carbon disulphid is purchased as a liquid in iron drums or tin cans and weighs about $10\frac{1}{2}$ pounds per gallon at ordinary temperatures. Upon exposure to air the liquid evaporates or volatilizes, forming a foul-smelling gas that is about twice as heavy as air. Because the gas is heavier than air and evaporates more quickly if a larger surface of the liquid is exposed to the air, the liquid should be poured out into shallow pie tins or similar shallow dishes and placed upon the top of the seeds to be fumigated. Seeds will not be injured or poisoned if the liquid is sprinkled or poured directly upon them. In estimating the amount of carbon disulphid needed, the amount of cubic space in the container in which the fumigation is done should always be considered—not the amount of space occupied by the seeds.

If used according to directions, carbon disulphid will not injure the germination of thoroughly dry seeds or affect their value for

food. The disagreeable odor passes away after seeds fumigated have been aired. While carbon disulphid has become a standard fumigant and has been used for years without trouble by many individuals and firms, it is always timely to call attention to the fact that the gas is explosive and inflammable if fire is brought close to it during fumigation. By fire are meant even a lighted cigar, lighted lantern, or the spark from an electric fixture.

Seeds to be fumigated should be placed in an air-tight container. This may be a tin pail, wash boiler, barrel lined with heavy paper, galvanized-iron garbage can, or other receptacle, or a specially constructed fumigation box or room, according to the amount of seed to be fumigated. One of the simplest satisfactory containers for fumigation on a small scale is a water-tight barrel. The tighter the receptacle the better the results. Satisfactory results can not be secured if fumigation is attempted in a room full of cracks.

Carbon disulphid should be used at the rate of from 4 to 20 pounds to each 1,000 cubic feet of space to be fumigated, the amount to be used varying with the tightness of the container and the temperature. The liquid should be poured over the top of the seeds to be fumigated or poured into shallow dishes set upon the top of the seeds. It quickly vaporizes, and as the gas is heavier than air, it sinks to the bottom of the container, filling all the air spaces. Fumigation should continue from 24 to 48 hours, although most of the actual killing is done during the first 6 to 8 hours of exposure. It is always better to use too much rather than too little carbon disulphid.

Beans, cowpeas, and peas can be stored and fumigated conveniently in water-tight barrels. These should be filled to within a few inches of the top with seeds. In fumigating, pour one-half cup or more of carbon disulphid on the seeds and then cover the top of the barrel with a double thickness of heavy wrapping paper tied tight around the top, or several sacks weighted down with boards. A wooden cover is also useful in keeping in the fumes.

Fumigation with carbon disulphid to give the best results should be carried on at or above a temperature of 75° F. It is not effective at temperatures below 60° F. After fumigation the seeds should be examined occasionally and given a second or third fumigation should living weevils be found.

Carbon disulphid costs from 6 to 25 cents a pound. The following quotations were made during January, 1922, by a large producer of carbon disulphid:

55-gallon drums of 550 pounds, at 6½ cents per pound, drums $12 extra.[17]
10-gallon drums of 100 pounds, at 7½ cents per pound, drums $5 extra.[17]
5-gallon drums of 50 pounds, at 7½ cents per pound, drums $5 extra.[17]

[17] Cost of drum refunded if drum is returned f. o. b. factory in good condition within four months of shipment.

50-pound cans, at 12½ cents per pound, including can.
10-pound cans, at 17 cents per pound, including can.
5-pound cans, at 20 cents per pound, including can.
1-pound can, at 25 cents per pound, including can.

To the above price must be added transportation costs. Farmers throughout the country can purchase carbon disulphid of local drug stores, but prices under such conditions often are exorbitant. County agents, boards of trade, or other public-spirited local organizations can purchase carbon disulphid and furnish it at cost to farmers in vicinity. This has been done in certain southern towns with the result that farmers have secured carbon disulphid of excellent quality [18] at lowest price. If local firms can not supply carbon disulphid, the names of firms in a position to fill orders may be obtained upon application to the Bureau of Entomology, U. S. Department of Agriculture.

Remember, if you do not get results with carbon disulphid the trouble is (1) with the way you apply it; (2) your container is not tight; (3) your dealer has sold you poor liquid; or (4) you have fumigated when it is so cold that no one can get good results.

Remember that large business firms and many farmers use carbon disulphid successfully and that its use on farms is on the steady increase. Nothing speaks better for any control measure than its steady use by successful business men, no matter whether they are farmers or seed brokers.

CARBON TETRACHLORID.

Carbon tetrachlorid (CCl_4) is a fumigant that has been used as a substitute for carbon disulphid in fumigation work, since it has the advantage over carbon disulphid of being noninflammable. When pure, carbon tetrachlorid is a thin, transparent, colorless liquid, with a pungent, aromatic odor. Except for being noninflammable, it is similar to carbon disulphid in all essential features, from the standpoint of application. It costs from 11 to 60 cents a pound and is not more than one-half as effective as carbon disulphid. It is not likely to take the place of carbon disulphid because of its inferior killing qualities and its somewhat great cost per pound. Its great advantage is its noninflammability.

If carbon tetrachlorid can not be had from local firms the names of firms supplying this chemical may be obtained upon application to the Bureau of Entomology, U. S. Department of Agriculture.

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[18] Unscrupulous dealers sometimes sell inferior lots of carbon disulphid. Dealers selling liquid containing less than 98 to 99 per cent actual CS_2 violate the Federal Insecticide Act and are liable to prosecution in Federal courts.

HYDROCYANIC-ACID GAS.

Fumigation with hydrocyanic-acid gas is recommended when large quantities of beans, peas, cowpeas, or chick-peas are found infested

FIG. 26.—Carload lots of 240-pound sacks of chick-peas as stacked in badly infested warehouse. Samples taken throughout length of sack proved that hydrocyanic-acid gas penetrated to the very center and that infestations were killed.

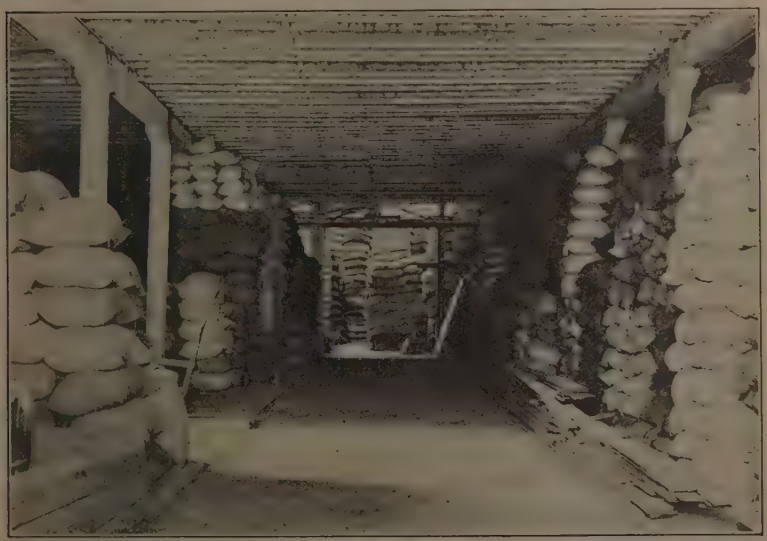

FIG. 27.—Interior view of warehouse containing thirty thousand 240-pound sacks of chick-peas with a retail value of $864,000 at time of treatment. Infestations breaking out under such abnormal storage conditions were controlled by fumigation with hydrocyanic-acid gas.

with weevils. The seeds must be in sacks and so stacked that the gas can reach several sides or portions of the sacks. Chick-peas stored in

240-pound sacks, and stacked as shown in Figures 26 and 27, were almost perfectly protected by fumigation. It has been found in the fumigation of warehouses, sometimes as large as 150 by 150 by 20 feet, and containing as many as thirty thousand 240-pound sacks of chick-peas, that hydrocyanic-acid gas can be depended upon to eliminate infestations almost completely. Fumigation with this gas for the control of bean and pea weevils has proved so satisfactory that its use is now an established practice with certain firms. The dosage should be increased from 1 to 2½ pounds of cyanid for each 1,000 cubic feet of space to be fumigated. **Since it is extremely poisonous, hydrocyanic-acid gas should be used only by responsible persons who are thoroughly informed on the subject of fumigation.** As the gas is lighter than air and readily escapes, does not injure the seeds for planting or for food, injures no warehouse equipment, and is noninflammable when mixed with air in the proportions used in fumigation, it lends itself for use in almost any warehouse section if the fumigation is properly timed and supervised. For further information secure from this department Farmers' Bulletin 699 and Department Bulletin 872, which give full particulars of procedure.

HEAT.

Heat as a means of killing weevils in legumes is growing in favor. Small quantities of seed grown on the farm or in the town garden can be treated by placing them in an oven after they have been spread rather thinly in shallow pans and heating them to 120° to 145° F. for several hours. An old remedy is to dip seeds into boiling water for one minute. Holding seeds in boiling water for more than one minute will injure their value for planting purposes and exposure for even one minute has been known to affect germination. On removal they should be spread out immediately and dried rapidly.

Weevil development in large quantities of beans, peas, and cow-peas can be stopped by a process known as kiln-drying. This process consists in heating the seeds to a temperature of 120° to 145° F., or higher, while they are being passed through a machine called a drier. This treatment not only removes a portion of the moisture in the seeds but also kills all insects in them. The loss of moisture may be an item of importance if sales are made by the pound, yet investigators claim that seeds containing 20 per cent of moisture or less are not easily infested by weevils, hence excessive drying with the heat not only kills the weevils but renders seeds less susceptible to re-infestation.

The embryos of the common bean weevil are killed when exposed to 125.6° F. for 10 minutes; the newly hatched larvæ die in 7 minutes

at 131° F.; full-grown larvæ in beans die in 20 minutes at 131° F.; and pupæ die in beans when exposed for 25 minutes at 131° F. Adults are killed by a 4-minute exposure to 131° F. These data can not be relied upon when large masses of seed are to be treated. The investigator who obtained them found that 9 hours were required for the center of 2 quarts of beans inclosed in a tight paper bag to reach the surrounding temperature of 131° F. Cowpeas infested with the four-spotted bean weevil were not absolutely sterilized from an insect standpoint when exposed to 140° F. for 5 minutes, though all the weevils were killed when the seeds were exposed to this temperature for 10 minutes in an oven. These results in killing the four-spotted bean weevil were secured under conditions more favorable than those likely to occur in commercial bean establishments, hence it was recommended that seeds be exposed in commercial treatment to 146° F. for 20 to 30 minutes. Temperatures above 150° F. seemed to weaken the resulting plants, but germination took place even after the seeds had been subjected to 190° F. for 10 minutes. Commercial coffee roasters are used by certain bean brokers for the destruction of weevils by heat. Seeds have been treated by the carload in such roasters and guaranteed to remain free from injury by bean weevils at least during transit in carload lots. A list of firms that manufacture apparatus for heating seeds will be furnished upon application. As is done in kiln-drying, the seeds should be spread out in order that all may be affected quickly and uniformly by the heat. When thus spread out an exposure to 131° F. for 1 hour should be sufficient.

Heat is not recommended for the control of the broad-bean weevil in broad or Windsor beans. Exposure to temperatures ranging from 120° to 140° F. for 5 to 40 minutes did not kill this apparently more hardy insect and the higher temperatures had an injurious effect upon germination.

COLD AND COLD STORAGE.

Weevils will not feed and cause damage at low temperatures. It is not known at what temperature development ceases, but no development takes place at or below 50° F. Cowpeas can be kept free from weevils if held in storage at a temperature of 32° to 34° F. It is claimed that exposure for a season at this temperature does not affect the germinating power of the seed. Investigations conducted in this bureau and not yet completed indicate that no stage of the common bean weevil can withstand 56 days of cold storage at 31 to 32° F., although they may survive more than 66 days at 36° F. The larvæ, it appears, succumb to cold storage temperatures more readily

than do pupæ or adults.[19] The storage room should be kept as dry as possible and the seeds should be handled in sacks as in warehouses. It is interesting to note that cowpeas held for a season at 32° to 34° F. were found to lose their germinating power no sooner on removal to normal temperatures than cowpeas not thus exposed to cold. Seeds removed from cold storage to warm temperatures are likely to sweat, and if care is not taken to eliminate this surface moisture by drying or proper ventilation moldiness may result. There is some doubt as to the real need of incurring the expense of cold storage as seeds can be protected more cheaply by fumigation under storage conditions thought by the majority of seed owners to be better for the seeds.

LIME OR DUST AS PROTECTION TO SEED.

In the Southern States, where weevils cause such great injury to stored seeds, certain farmers have resorted to mixing their seed cowpeas with dry road dust or air-slaked lime. Tests prove that the storage of cowpeas with air-slaked lime at the rate of 1 part by weight of lime to 6 to 8 parts of peas is a great help in protecting seeds. The dust or lime does not necessarily kill the weevil grubs developing in the seeds if these are already in the seeds at harvest time, but it prevents adult weevils either from emerging or, if they succeed in emerging, from laying their eggs on the seeds for successive generations. The dust or lime, in other words, prevents continued breeding in storage. Either substance would probably be a nuisance if mixed with cowpeas intended for food if the seeds contained many emergence holes, as the lime or dust would work into these holes and be difficult to remove. If seeds are known to be free from weevils and are stored in tight barrels, bins, or other similar containers, a top layer of air-slaked lime about ½ to 1 inch thick, if maintained, will prevent weevils from gaining access from without and starting an infestation.

COMMUNITY EFFORT TOWARD CONTROL.

Anyone can protect beans and peas from further weevil injury after they are once dried and in storage. If loss occurs in storage, owners have only themselves to blame, for weevils can be effectively controlled at a cost very slight as compared with the value of the seeds protected and the increased value of the seeds after thorough treatment.

But no one person can prevent his beans and peas from becoming infested while they are developing in the garden or field unless he

[19] Original data (unpublished) by A. O. Larson and P. Simmons.

and his neighbors are willing to get together and pledge to treat their seeds in storage. Many adult weevils fly to fields from storage, or remain in fields harvested in a slack manner. A negligent neighbor may be the cause of much neighborhood infestation by the flying of his weevils to developing crops or into warehouses.

Community effort to reduce weevil losses can be made effective in localities where beans and peas are grown on a commercial scale. It is doubtful if concerted action can be secured in towns or cities where there are many small gardens yielding but a few seeds, for these small quantities of seed are of too little value to move their owners to action. The University of California during 1918–1920 conducted a campaign of community effort, in San Mateo County, Calif., directed against the broad-bean weevil (p. 19) and found that by working through the county agent and fumigating the crops after they were placed in storage the infestation in the field was reduced from 43 per cent in 1918 to 21 per cent in 1919 and to 17.8 per cent in 1920. The county agricultural agent has here a worth-while field for action along with his many others. To succeed, all farmers in a district should treat their seeds and destroy promptly refuse from cleaning machines.

TREATMENT DOES NOT PREVENT REINFESTATION.

Treatment of legumes subject to infestation by weevils that can breed generation after generation in storage will not keep them free from weevils if they are stored so that adult weevils can get to them and lay eggs on them. The application of remedial measures may kill all weevils in the seed at the time of treatment, but it should be remembered that no treatment has a lasting effect in preventing reinfestation from outside sources. Seeds once treated should be stored in rooms free from adult weevils, or placed in tight barrels or sacks made of closely woven material, and should be examined occasionally as a guard against subsequent infestation.

When large quantities of seeds are brought together under one roof, they usually represent the crops of many farmers whose local conditions may have varied to such an extent that one carload lot of seed may be free of infestation while the next may be slightly or heavily infested. Experimental work has proved that sacking seeds in one thickness of light-weight close-weave muslin will prevent uninfested seed from becoming infested even though there are many weevils and weevilly seeds close by. It is not practical in large seed warehouses to use sacks of light-weight muslin, yet a study in 1917–18 of conditions in large warehouses containing many carload lots of seed indicates the value of closely woven sacks. Jute sacks with

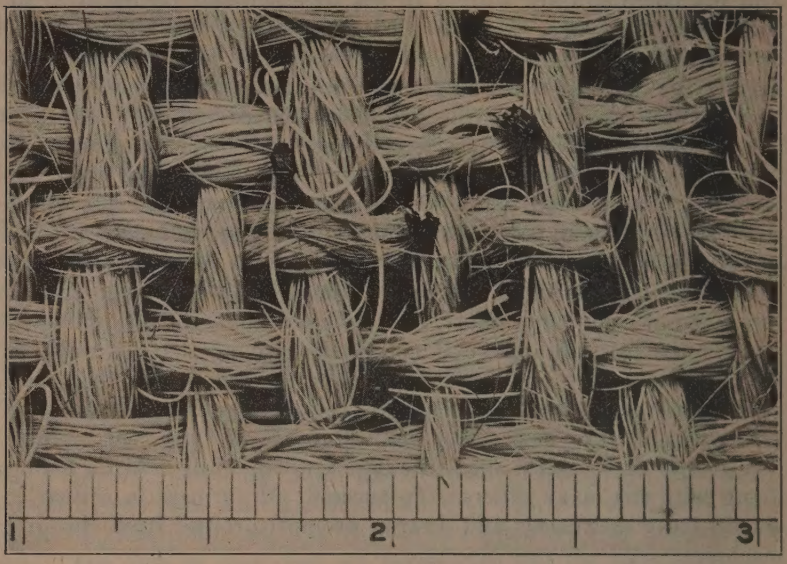

FIG. 28.—Section of jute sack having four strands to the inch. Such sacks are of no value in preventing spread of infestations from sack to sack in warehouses. The adult weevils can leave or enter such sacks at will.

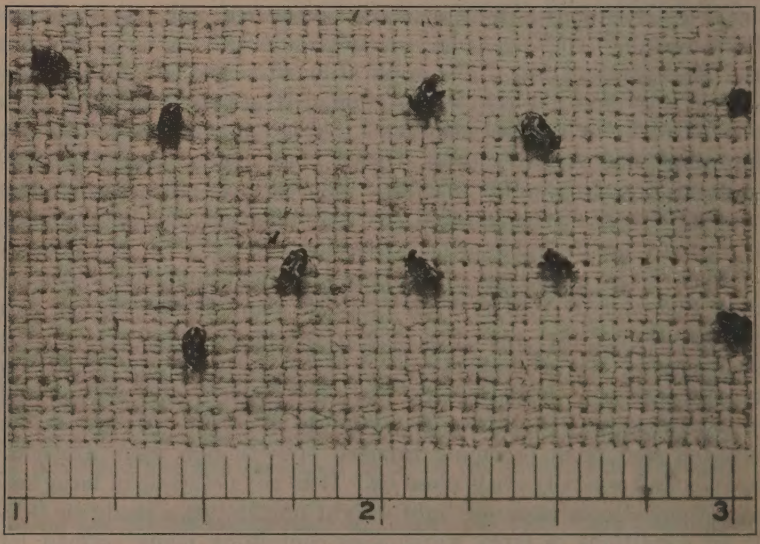

FIG. 29.—A heavy cotton close-woven sack with 24 strands to the inch. Sacks made of this material are on the market and have proved their effectiveness not only in preventing weevils from leaving the sacks but also in protecting uninfested seeds from infestation from without.

but four strands to the inch (such as shown in Fig. 28) are no protection to the seeds within the sacks and do not prevent weevils developing in the sacks from crawling out and migrating to and laying their eggs upon seeds in other sacks of similar weave. But seeds sacked in heavy cotton sacks of close weave with 24 strands to the inch are apparently perfectly protected from infestation from without (Fig. 29). Some such sacks contained badly damaged and heating seed but the infestation was held within them and prevented from spreading to adjoining sacks by the tightness of the sacks. The common bean weevil, the cowpea weevil, and the four-spotted bean weevil can eat holes in paper sacks and escape, but do not eat through cloth. There is a great deal in favor of a tight cloth sack, not only for protecting uninfested seeds from infestation from outside sources but also in preventing infestations from spreading.

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